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INJECTION LIMITED GUNN DIODES

Final Technical Report

by

U. Traxlmayr and H. W. Thim

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

As a continuation of our experimental work on epitaxial growth of high quality GaAs and on low resistance ("ohmic") contacts (Grant No. DAERO-78-G-049) devices with field effect transistor cathode contacts for controlling injection have been fabricated and tested. The theoretically predicted improvements on bandwidth and efficiency have not yet been observed experimentally. On the contrary, performance of the Gunn diode always deteriorated whenever a bias voltage was applied to the gate, although domain

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Summary

As a continuation of our experimental work on epitaxial growth of high quality GaAs and on low resistance ("ohmic") contacts (Grant No. DAERO-78-G-049) devices with field effect transistor cathode contacts for controlling injection have been fabricated and tested. The theoretically predicted improvements on bandwidth and efficiency have not yet been observed experimentally. On the contrary, performance of the Gunn diode always deteriorated whenever a bias voltage was applied to the gate, although domain formation could be suppressed. The results indicate that the basic concept of using a field effect cathode as the injection limiting contact is correct and that there is reasonable hope that improved operation should be possible with this device if the correct doping density and a sufficiently small gate length is used.

Table of Contents

Keywords

Transferred Electron Amplifier/Oscillator (Gunn Diode)
Injection Limiting Cathode Contact
Planar Gunn Diode with Limited Electron Injection

1. Device Physics and Technology

It is well known that Gunn diode performance should improve drastically if the electric field in the active region is fairly uniform, i.e., if domain formation is prohibited. One way of achieving this is to operate a regular Gunn diode with ohmic contacts in the LSA mode proposed in 1966 by Copeland. However, it is now generally agreed that LSA operation is extremely sensitive to doping fluctuations and circuit adjustments resulting in unreliable operation. The second concept for achieving uniform field operation is the "cathode injection control concept" proposed in 1968. Although encouraging results have been obtained with InP devices having "two-zone" cathode contacts there ist still no convincing evidence that injection is really limited as all devices have been operated so far only at transit-time frequencies and not at higher non-transit-time related frequencies a truly injection limited Gunn diode should be capable of.

Subject of this contract was to investigate the possibility of using a field effect transistor as the injection limiting cathode contact which injects electrons into the drift (Gunn effect) zone. The advantage of this structure is that the amount of injection can be adjusted externally by controlling the gate voltage. This structure is shown schematically in Fig. 1. Typical dimensions used during the present investigation are also shown in the figure. Standard lithographic processes have been used for fabricating these dimensions which, unfortunatelly, could not yet been optimized due to our limited technological capabilities. In particular we were not able to produce gates less than 3 microns long which would be desirable for minimizing the voltage drop across the field effect cathode, i.e., the series resistance. This voltage drop, we believe, is responsible for the inferior performance obtained with these devices as will be discussed below.

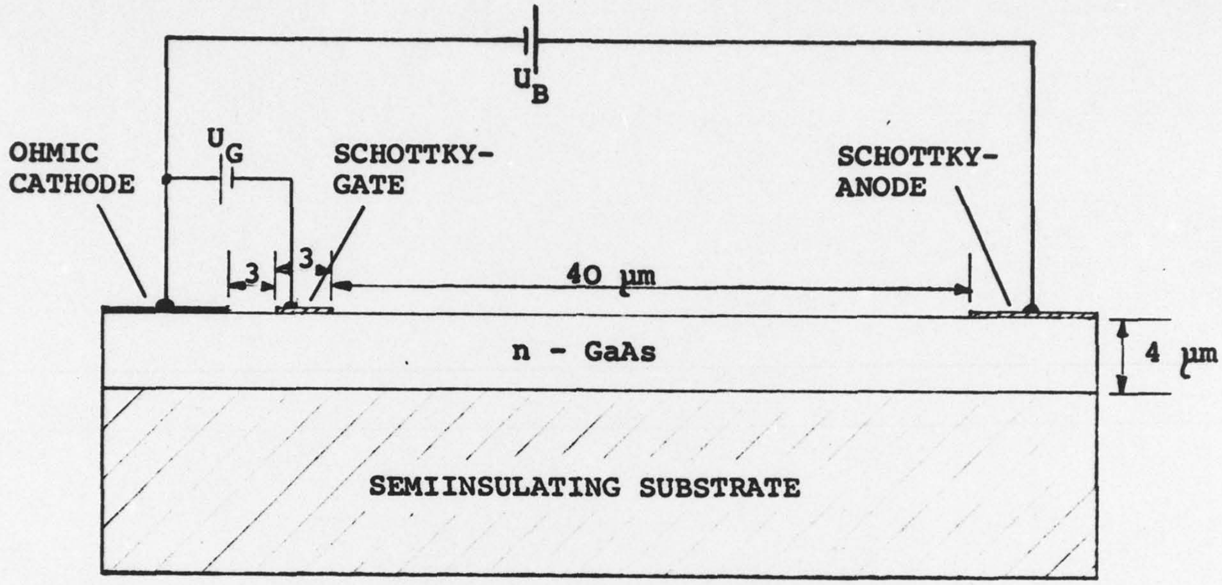

Fig.1 Scheme of tested device and bias circuit.

The doping level of the epitaxial layer has been varied between $5x10^{14}$ cm^{-3} and $2x10^{15}$ cm^{-3}. The n_oL product was varied between $2x10^{12}$ cm^{-2} and $8x10^{12}$ cm^{-2}. Since this is higher than the critical value for domain formation one expects dipole domain formation at least somewhere in the active region if not at the field effect (gate) electrode. However, domain formation should not occur if a negative voltage is applied to the gate first and then slowly decreased after the bias voltage U_B is switched on. Of course, the two voltages have to be adjusted carefully in order to avoid avalanche breakdown especially at large negative gate voltages. The optimum value of the gate voltage is reached when the field in the drift zone is uniform.

2. Experimental Results

a) Devices with ohmic anode contacts

In early experiments we had indications that the field in the active region never exceeded the threshold field. Probe measurements then revealed that a stationary anode domain had formed which absorbed most of the bias voltage applied to the device. This difficulty was removed by replacing the ohmic anode contact by a "Schottky-Anode" Contact.

b) Devices with Schottky anode contacts

The devices had been mounted in a reflection-type amplifier circuit using stripline techniques. A bias-tee was used to separate the microwave signal from the bias pulses and a double stub tuner was used to transform the line impedance (50 Ohms) to a level high enough to obtain reflection gain of reasonable magnitude. The values of reflection gain obtained under stable conditions, i.e., for gate voltages sufficiently high to suppress transit-time dipole layer oscillations, however, never exceeded unity. This led us to conclude that either the drift region was biased below threshold and both DC and AC voltages were dropped across the field effect cathode thus acting as a large parasitic series resistance or the drift region actually exhibited negative differential resistance but this was wiped out completely by the large positive series resistance of the field effect transistor cathode. If one accepts one of these explanations it is then obvious that the series resistance must be made as small as possible in order to have the frequency-independent negativ resistance of the drift region appearing at the external device terminals.

3. Conclusion

Since it is not difficult to imagine that a device with a sufficiently small series resistance, i. e., gate length, will exhibit amplification, there is no point in terminating the work at the present stage. We will therefore continue this work in our laboratory and will keep ERO informed about the progress of this project.

Student who received remuneration:

Dipl.Ing.Ulrich Traxlmayr